ABSTRACT

The Ph.D. thesis research focused the processing of W-based matrix composite materials having a homogeneous structure for electric contact parts and high currents. Also, the research comprised the optimisation of the processing technology for these materials by powder metallurgy route.

The objectives researches were:

- The approaching of some material systems providing the compromise between the working terms of high current contact parts requiring high electric conductivity and high electric resistivity for thermal chocs due to the electric arch. Three material systems have been researched: W-C, W-Cu-Ni, W-Cu-Co, having 10%, 20%, 30% and 40% of Cu respectively Ni or Co at 2% content.
- The processing of the composite materials from the above mentioned systems by mechanical alloying in order to obtain powder particles with high chemical homogeneity and compaction and sintering behaviour as good as possible.
- The processing of electric contacts from composite powder particles by powder metallurgy technologies.
- The determination of electric parameters (electric conductivity, electric strength, electric resistivity and heat strength).
- The determination of the correlation between the specific structures of the processed materials by powder metallurgy and the technological parameters related to the electric characteristics of the manufactured contacts.

There have been studied 12 material types from those 3 material systems mentioned above. The 12 types have been mechanical alloyed and the milling time (2, 4, 6 h) influence on the powders' morphology and composition have been studied.

After the mechanical alloying process development, the following conclusions are drawn:

1. From the point of view of the particle size evolution along the mechanical alloying time, all 12 material types behaved constantly, no matter the milling time: 2h, 4h and 6h;
2. The powders morphology after 6h of mechanical alloying is irregular, having shapeless surfaces;
3. The powders outer surfaces are rough, visible from fig. 2.19-2.30 where powders conglomerates can be explained by the rough surfaces;
4. The particle size distribution is irregular, being an advantage from the point of view of compaction behaviour; it is well-know that the monosized powder particles cannot be compacted;
5. The powders having 20% respectively 30% Cu are the smallest powders;
6. For this Cu content, the maximum mesh size of the particle size distribution is (28,8 – 36) μm for 20% Cu content respectively (23,4 - 36) μm for 30% Cu content of the powders;
7. It can be concluded that the mechanical alloying of W-based composite powder particles may have the strongest effect regarding the decreasing of the powder size for (20-30)% Cu content of the powders;
8. For 10% and 40% of Cu, the particle size distribution of the processed powders is different;

9. For W-40Cu respectively W-40Cu-Ni the particle size increases due to the large Cu content remained out of the W network and leads to conglomerates occurring;
10. W-Cu-Co system is different from the point of view of the particle size distribution evolution depending on Cu content which is relatively regular: 28,8 μm (20%Cu); 36 μm (30%Cu) and 36 μm (40%Cu), meaning the Co content allows Cu dispersion in W network;
11. From the point of view of phase structural composition, RDX analysis on the processed powder particles revealed the following:

1. The remaining Cu is higher for W-Cu samples than other 2 composite systems having 2% Ni respectively Co;

2. Ni and Co allow the Cu atoms dispersion in the mechanical alloying product as the result of these 3 elements mixing;

3. $W_{0,6}Cu_{0,4}$ compound having cubic crystallisation and the lattice parameter A = 0,31702 – 31793 nm is for the first time synthesized in this research and mentioned here; the variation of this lattice parameter "A" depends on the Cu content: (10, 20, 30, 40) %.

In the third chapter the influence of compaction and sintering parameters on the density, sintering volumetric swelling, porosity and microscopic structure of the electric contacts processed by mechanical alloyed powder particles have been studied.

The influence of the compaction pressure (400 and 600) MPA and the dwell sintering time (1 and 3) hours at 1180 ^{0}C sintering temperature has been studied.

On the experimental data the following aspects can be underlined:

1. The samples density is influenced by the mechanical alloying time, Cu content, compaction pressure and dwell sintering time;

2. For all 3 material systems, the higher densities are obtained for samples prepared for 6 hours of mechanical alloying, compacted at 600 MPa and 3 hours dwell time at sintering temperature;
3. The maximum density is for W-Cu samples, namely 90W10Cu;
4. The averaged density is for W-Cu-Co samples, namely 88W10Cu2Co;
5. The swelling effects and porosity of the samples matches their densities;
6. The porosity decreases along the Cu content;
7. The best porosity is for the samples 58W40Cu2Ni, processed from powders mechanical alloyed 6 h, compacted at 600 MPa, sintered at 1180^0C for 3h;
8. The higher porosity corresponds to the samples of 58W40Cu2Co powders, processed at the same parameters above mentioned;
9. The samples processed from mixed powders have larger porosity than the same samples prepared from mechanical alloyed powders.

The fourth chapter comprises the experimental results regarding the electric tests of the 12 powder types processed by mechanical alloying. The relationship between the sintered samples' structure and electric properties has been drawn and here are the conclusions:

- The electric conductivity is an important parameter for the sintered electric contacts during functioning;
- On the tables data and graphic representations there are the following conclusions:
- The electric conductivity is influenced by Cu content, mechanical alloying time, compaction pressure, dwell time and porosity;
- For all 3 material systems the best values for the electric conductivity are for the samples processed from powders

mechanical alloyed for 6 h, compacted at 600 MPa and dwell time of 3 h at sintering temperature;

- The maximum values are for 60W40Cu system;
- The average values are for the samples W-Cu-Co, namely 58W40Cu2Co mechanical alloyed for 6h, compacted at 600 MPa and dwell time for 3 h.
- Minimum was reached for the samples of W-Cu-Ni. The min. value is for 88W-10Cu-2Ni, mechanical alloying for 0h, compaction pressure 400 MPa, dwell time 1h;
- The electric contacts form W-based composite powders get less heated as Cu content increases. The most performing are from W-Cu-Ni and W-Cu systems, and the less performing are W-Cu-Co;
- The electric parameters (electric conductivity, resistivity and strength) can be evaluated by the mathematical models performed by STATISTICA programme, fig. 4.18-4.41.

The main original contributions of Ph.D. thesis' author, depicted from the literature, are:

- W-Cu, W-Cu-Ni systems approaching, having (10, 20, 30, 40)%Cu;
- W-Cu-Co system is not visible in literature. Its approaching is based on economic and environment protection terms.
- Processing of composite powders;
- Identifying of $W_{0,6}Cu_{0,4}$ compound in composite powders composition from the systems W-Cu, W-Cu-Ni and W-Cu-Co processed by mechanical alloying;
- The morphological characterisation of the processed composite powders by mechanical alloying;

- The study on the influence of compaction pressure, 400 MPa and 600 MPa on the physical and structural characteristics of the electric contacts manufactured from the composite powders;
- The study on the influence of the dwell time (1 h respectively 3h) at sintering temperature 1180 ^{0}C on the physical and structural characteristics of the electric contacts manufactured from the composite powders;
- The study of the influence of the electric contacts porosity on the electric properties of the W-based composite electric contact parts.